Integrated Protection of Stored Products
IOBC-WPRS Bulletin Vol. 81, 2012
pp. 193-197

Fumigation of fresh herbs with phosphine as a new quarantine treatment

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Abstract: Introduction of new pests into new habitats is the main concern of all agricultural quarantine authorities. To prevent these dangers all countries enforce quarantine regulations on agricultural products demanding that the product will be free of live insect pests. To provide high quality products the fresh spices growers must market the harvested herbs within 3 days kept at temperature of about 4°C. Today exported herbs are fumigated with methyl bromide (MB) to achieve a total mortality of all insect developmental stages found in the products, MB is highly phytotoxic and only effective as a pesticide when the fumigation is carried out at temperatures over 21°C. To develop fumigation technology that will be suitable and effective to replace MB, experiments were carried out using phosphine. Experiments were carried out under laboratory conditions at temperature of 4°C and for 24h exposure time. The tested herbs were: dill, parsley, tarragon, basil, mint, sage, oregano, thyme and rosemary. The insect pests: *Laphigma* spp., *Prodenia* spp., Geometridae, thrips and *Bemisia tabaci* were collected at their adult and larval stage with the herbs from the field and they were exposed to the phosphine fumigation treatment. The effective concentration of the gas that was found suitable to attain complete mortality of all groups of tested insects was 700ppm. It was also found that the treatment killed all developmental stages of mites *Tetranychus urticae*. Most herbs had no quality deterioration due to the treatment even after 14d of storage, except basil and mint which were found sensitive to the treatment. These results indicated that phosphine fumigation can be an effective quarantine treatment that can control field insect pests after exposure of 24 hours at the low temperature of 4°C and can be considered as MB alternative treatment.

Key words: fresh herbs, phosphine fumigation, quality preservation, quarantine treatment, low temperature, insect control, methyl bromide alternative

Introduction

Israel has been exporting fresh herbs since the late 70's. In 1995 Israel exported about 1,200 tonnes of fresh herbs and since then the yield increased yearly reaching the 6,000 tons during 2010. The most common herbs exported are basil and chives which constitutes about 50 percent of the total herbs export. Other major herb species are coriander, roquette, mint, tarragon, rosemary and dill along with 20 other species (Manor, 2004). The most common export destinations are England, Germany, France and Italy in Europe and the USA. Fresh herbs harvested in the field can be infested by different species of insects and other non-insect pests. Among the common pests that can be found within the herbs are: Lepidoptera; *Laphigma* spp., *Prodenia* spp., Geometridae, Pseudococcidae, *Bemisia tabaci*, thrips, snails and Acari (Tajer, 2009).

The introduction of new animals' species into new habitats, especially new pests is the main concern of all agricultural quarantine authorities. This results that, all plant protection authorities at the fresh herbs destined for export, demand that the exported herbs must be free of live insect pests as well as free of foreign matter, diseases, foreign flavor and odor in a

condition that will insure its quality when arriving at the destination (Sharon, 1985). Most of these goals can be achieved by the farmers in the field or at the packing house with the exception of accomplishing the 100% mortality demand of all pests which may randomly occur in the fresh herbs. In the past 3 years, there was a zero tolerance by the USA Animal and Plant Protection Inspection Services (APHIS) and even if one live insect was detected, the shipment was not accepted and the specific farmer could not export for the next following 3 months (Tajer, 2009). Consequently, since January 2009 most of the fresh herbs export authorities from Israel, mainly to the USA, have been in search of novel application methods.

In order to continue fresh herbs export, the USA and the Israeli authorities reached an agreement. Today all exported herbs are fumigated with methyl bromide (MB) to achieve a total mortality of all insect developmental stages found in the products. Although MB is an effective pesticide, when fumigating products as fresh herbs, it has two main drawbacks; it is highly phytotoxic and causes browning of the plant, and it is effective at temperatures that are higher than herbs storage temperature. Therefore, to achieve a successful fumigation, the herbs must be first heated to 21°C and then cooled again resulting in significant reduction of products' shelf life. Furthermore, since the phase-out of MB most of the product export destinations countries demand a minimal use of MB and implementation of alternative technologies (Jamieson *et al*., 2009).

Phosphine was first applied commercially as a fumigant for fresh fruit 7 years ago (Horn and Horn, 2004; Klementz *et al*., 2005). Phosphine, unlike MB is not phytotoxic; it can be applied during cold storage and it does not have an undesirable environmental effect because it is transformed into harmless amounts of phosphoric acid and phosphates by sunlight after its release into the atmosphere (Brash *et al*., 2009).

Horn *et al*. (2004) fumigated fresh fruit with pure phosphine, free of ammonia in fumigation chambers, cooling chambers or controlled atmosphere chambers at low temperatures. For fumigation they used VAPORPH_3OS®, manufactured by Cytec that was applied through the HORN DILUPHOS SYSTEM®. It was determined that the technology can be successful if the fumigation is carried out at a temperature between -1.5 and 15ºC, concentration between 700 and 3,500ppm (1-5g /m^3) and with exposure time of between 36 and 72 hours. Horn *et al*. (2004) determined that the best treatment conditions for fresh fruit fumigation are 1,500ppm for 48 hours at 0°C. No damage to the fruit has been detected and the shelf life of the fruit after this treatment was found to be similar to non treated fruit (Horn *et al*., 2004).

The results of the work by Horn paved the way for potential use of phosphine fumigation for fresh products. Although herbs pest management demands more restricted working protocols. To provide high quality products, the fresh herbs growers must market the harvested herbs within 3 days from harvesting and the herbs must be kept at cold temperatures of 4-6°C during the treatment. In this work, we attempted to provide a precise technology and working protocols that will able the fresh herbs industry exporting insect pest free products by implementing a pre-shipment Phosphine fumigation treatment suitable for use in the existing manufacturing process, maintaining product quality as well as its shelf life period and effectively replace MB.

Material and methods

Work was carried out in two stages. The first stage was under laboratory-controlled conditions and the second was a semi-commercial stage conducted in a cool room at the packinghouse. In both stages the tested herbs were: basil, mint, sage, thyme and rosemary.

The insect pests that were exposed to the treatment were: Lepidoptera; *Laphigma* spp., *Prodenia* spp., Geometridae, Aphididae, Aleyrodidae (*Bemisia tabaci*). All insect pests were collected at their adult and larval stages together with the herbs at the field.

Laboratory experiments

Desiccators of 2.8l were used as experimental fumigation chambers. The tested herbs 60g of weight, were placed into each of the desiccators together with their insect pests without disturbing the insects or moving them. Into each of the desiccators 500ppm phosphine was injected. After the injection the desiccators were placed in an incubator at a temperature of 4°C for 24h exposure time. After the exposure each of the desiccators were opened and aerated. The treated herbs and the tested insect pests were removed and placed in another incubator for additional incubation time of 24h at 28°C to determine the possibility of insect recovery. After the recovery, the herbs were examined visually for any indication of phytotoxic effects. The herbs were shaken on a white paper and examined for live or dead pests.

Semi-commercial trials

During the summer of 2009, seven fumigations were conducted at the packinghouse of "Jordan River Herbs", Mechola, Israel. An experimental fumigation chamber of $1m^3$ capacity was placed in one of the refrigerated rooms. The gas was circulated within the fumigation chamber with an inner fan of 300l/min capacity. The tested herbs were packed in their original exporting packages consisted of a special perforate plastic bag and a card box. There are 3 types of perforated bags providing different gas penetrability. All three were tested for their effect on phosphine gas penetration during the fumigation. Each box contained 1kg of herb. In each treatment approximately 25-40kg of different tests herbs: dill, parsley, tarragon, basil, mint, sage, chives, oregano, thyme, coriander, roquette and rosemary. The tested insects were: Lepidoptera; *Laphigma* spp., *Prodenia* spp., Geometridae, Pseudococcidae, Aphididae, *Bemisia tabaci*, thrips and Acari (*Tetranychus urticae*). The fumigations were carried out at temperature of 4°C at 24h exposure time. After exposure the fumigation chamber was opened, aerated and samples of the treated herbs were taken to the laboratory. At the laboratory, the pests were removed from the herbs and incubated at 28°C for 24h after incubation mortality was recorded. In addition, estimation of insect population was carried out on 160g herbs depending on the herb and the level of infestation. The fumigated herbs along with the control remained under refrigeration and their shelf life was tested for the next 2 weeks. Phytotoxicity was examined as well strait after the fumigation, a week after and 2 weeks after.

Results and discussion

The demands of pest management and quality control at the fresh herbs industry require addressing the necessity to control a big diversity of pest species as well as altering herbs verities. Achieving a successful treatment in a single fumigation treatment demands that the fumigation protocols have been tested on all pest and products. The effective concentration of phosphine gas to attain a complete mortality of all life stages of *Bemisia tabaci* was above 345ppm in the fumigation chamber space. This species is very sensitive to the treatment and mostly infests mint and sage leaves (Table 1). Sensitivity to the treatment of all the developmental stages of the Spider mites and Lepidoptera larvae was only in the concentration range of 935-1033ppm in space. Higher concentrations resulted in decline of mortality percentage (Table 1). This is probably due to decrease in respiration. As for Aphididae and thrips which were found only in the hot summer of July until mid August the

effective concentration was in the range of 541-935ppm (Table 1). Therefore the effective concentration of fumigation treatment with phosphine gas of fresh herbs at 4°C should be in the range of 900-1000ppm in fumigation chamber space.

Table 1: Estimated population size of insects (insects/kg), PH_3 concentration in the box and in the chamber-space (ppm) of the fumigated herbs at 4°C. (N.F. – Not Found)

		Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Trial 7**
Phosphine concentration	Product	-	271	784	903	958	-	1226
	space	345	541	926	935	1033	1175	1594
Aphididae	Sample size	5120	9760	23,120	N.F.	7	N.F.	66,500
	Mortality in %	89.7	98.6	100	-	100	-	99.5
Laphigma, Prodenia Geometridae	Sample size	1180	925	3,280	1,290	1,270	1,000	960
	Mortality in %	52.1	76.9	100	100	97.4	100	85.7
Thrips	Sample size	330	380	990	N.F.	5	N.F.	120
	Mortality in %	99.4	100	100	-	100	-	100
Bemisia tabaci	Sample size	77	42	66	1,590	260	1,480	160
	Mortality in %	100	100	100	100	100	100	100
Bemisia tabaci eggs	Sample size	N.F.	N.F.	N.F.	40,900	N.F.	N.F.	N.F.
	Mortality in %	-	-	-	100	-	-	-
Pseudococcidae	Sample size	N.F.	N.F.	N.F.	3,080	N.F.	1,317	N.F.
	Mortality in %	-	-	-	100	-	100	-
Tetranychus urticae	Sample size	40	N.F.	N.F.	33,180	1,531,250	24,890	43500
	Mortality in %	25	-	-	100	100	100	92.5
Tetranychus urticae eggs	Sample size	N.F.	N.F.	N.F.	612500	N.F.	N.F.	N.F.
	Mortality in %	-	-	-	100	-	-	-

When the quality of the herbs was tested, we found that mint leaves showed some leaves browning after the treatment along with the basil. The reason might be related to the sensitivity of these herbs to cold temperatures since the tests were carried out at 4°C and not the result of phytotoxic effect. Excluding basil and mint in all other herb species phytotoxicity was not found and their shelf life was not affected by the fumigation. These results indicate that this is an important technology that has the potential for the treatment of fresh herbs, but further research has to be made and commercially tested before implemention.

Conclusions

Phosphine is an effective fumigant that can control pests of fresh agricultural commodities. Phosphine fumigation is effective at low temperatures of 4°C in a 24h treatment. The

effective concentration was found to be in the range of 900 to 1000ppm. The effect of the fumigant has to be studied on other potential quarantine pests.

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